U. S. NAVAL PROPELLANT PLANT

INDIAN HEAD, MD.

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28 MAY 1964

From: Commanding Officer, U. S. Naval Propellant Plant, Indian Head, Maryland
To: National Aeronautics and Space Administration
George C. Marshall Space Flight Center
Huntsville, Alabama

Subj: Technical Summary Report on the Pneumatic Mix Process; forwarding of

Ref: (a) NASA-Defense Purchase Request No. H-61469 of 4 April 1963

Encl: (1) Technical Summary Report on the Pneumatic Mix Process

1. Enclosure (1) forwards the Technical Summary Report on subject process funded by reference (a).

2. Further technical effort has been suspended pending additional funding.

O. F. DREYER

BODO BARTOCHA
By direction

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Encl: (1): - Technical Summary Report on the Pneumatic Mix Process

SUMMARY

An installation for continuously manufacturing composite propellant, by means of the Pneumatic Mix Process, has been constructed. Three runs, where 15KS 1000 JATO propellant was continuously mixed, cast and deaerated were accomplished with no processing difficulty or equipment malfunction. Evaluation of the cured propellant indicated the product was homogeneous, dense and possessed mechanical and ballistic properties comparable to conventionally processed material.

Plant modifications to allow processing of HB series composite propellants have been completed.

Preliminary ballistic, physical and rheological properties of batch-mixed HB series composite propellant have been determined.

DISCUSSION

The pneumatic mix processing equipment was initially installed in a location suitable for the processing of explosive materials. The accompanying drawing, Figure 1, delineated the initial layout of the equipment in Building 686.

After the demonstration facility was checked out with inert materials, three live runs of 15KS 1000 JATO propellant were accomplished with no processing difficulty or equipment malfunction. Approximately 40 pounds of propellant was continuously mixed, deaerated and cast at a rate of 200

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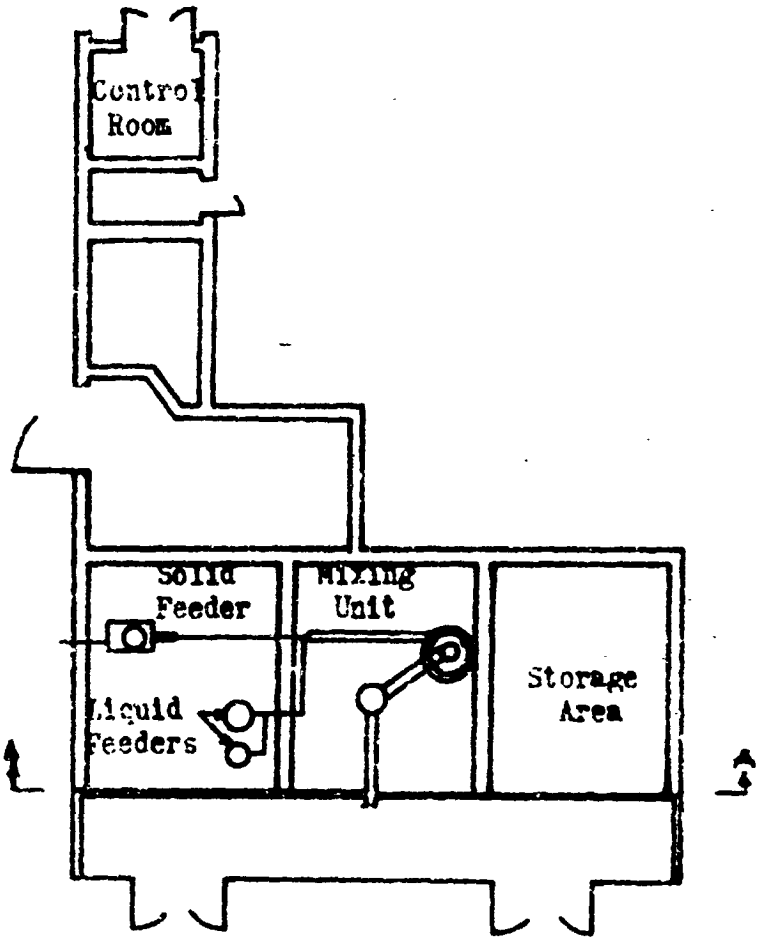

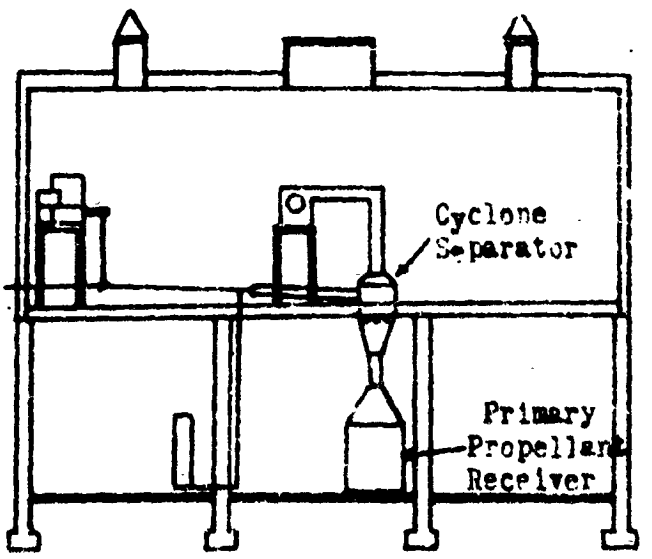

SECTION A-A

FIGURE 1. EQUIPMENT LAYOUT IN BUILDING 686 FOR THE PNEUMATICITY PROCESS

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lbs/hr during each of the runs. The propellant was cured and the subsequent x-ray analysis indicated the material contained essentially no voids.

Microscopic examination of the pneumatically mixed propellant from the first run revealed that the material was dense, with no gas bubbles visible under high magnification. The solids of the formulation were evenly distributed throughout the mass.

Preliminary results on the cured material produced during the first continuous runs are provided in Tables I, II, III and IV. The particle size distribution of the oxidizer feed for the third run was coarser than for the other runs.

The data indicates that pneumatically mixed 15KS 1000 JATO propellant possessed a higher burning rate than the specifications.

In order to account for the increased burning rate, the particle size distribution of the oxidizer in the propellant was microscopically determined. These measurements indicate that the particle size of the oxidizer was no more than that specified in the SPIA Manual, and that there was no measurable attrition during mixing. Preliminary microscopic examination of the propellant sample did reveal, however, that there are a larger number of agglomerates of the burning rate modifier between 5μ and 30μ in size in the conventionally processed propellants than in pneumatic mixed propellant.

The HB series composite propellant, utilizing a relatively viscous prepolymer, are normally processed at elevated temperatures.

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Table 1

THE COMPOSITION OF 15KS 1000 JATO PROPELLANT MANUFACTURED BY MEANS OF THE PNEUMATIC MIX PROCESS

	% Oxidizer	% Burning Rate Modifier	Density
Run #1			
Section			
G*	73.8		1.65
I	74.8		1.66
L	75.1		1.65
Run #2			
Section			
B	74.2	0.13	1.65
I	75.7	0.12	1.63
S	75.7	0.15	1.62
N	74.5	0.14	1.61
Run #3			
Section			
B	73.4	0.14	1.61
E	75.4	0.15	1.62
K	75.8	0.14	1.62

*The subscript letters refer to sections cut along the length of the grain.

The specifications call for a composition of 75.0% oxidizer and 0.15% burning rate modifier with a density of 1.64 g/cm^3.

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Table II

PHYSICAL PROPERTIES OF PNEUMATICALLY MIXED 15KS 1000 JATO PROPELLANT AND COMPARISON WITH BATCH MIXED MATERIAL

	Temperature, -65° F			Temperature, 77° F			Temperature, 165° F		
	S_m psi	E_m %	YM psi	S_m psi	E_m %	YM psi	S_m psi	E_m %	YM psi
Run #1	1068	1.34	82200	205	3.01	9230	99	2.77	5007
Run #2	1657	1.13	157000	221	3.20	10021	92	3.27	4256
Run #3	1022	0.69	150000	222	2.89	10477	97	2.53	5355
Pilot Plant Batch Mixed (avg. of 12 batches)				164	2.2				

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Table III

BALLISTIC PROPERTIES OF PNEUMATICALLY MIXED 15KS 1000 JATO PROPELLANT

Run No.	Burning Rate (in/sec)	$\bar{F}_b$ (lbsF)	Isp (Del.) (sec.)	Corrected Isp (sec.) at 1000 psi with 15° Cone	% Efficiency ($\frac{C_F \text{ Del.}}{C_F \text{ Theor.}} 100$)
1. (TPC Firing Data)					
Section F $\bar{P}_b$ = 814 psi T = 70° F	0.311	313	197.7	207.3	97.9
Section H $\bar{P}_b$ = 908 psi T = 70° F	0.330	353	303.9	206.5	96.6
2. (TPC Firing Data)					
Section E $\bar{P}_b$ = 871 psi T = 70° F	0.332	304	200.1	204.4	97.4
Section K $\bar{P}_b$ = 873 psi T = 70° F	0.320	307	200.4	204.7	98.5
3. (TPC Firing Data)					
Section A $\bar{P}_b$ = 947 psi T = 70° F	0.370	396	205.1	209.7	100.0
Section B $\bar{P}_b$ = 901 psi T = 70° F	0.381	382	210.9	215.7	99.4

Burning Rate from SPIA = 0.300 at 900 psi; T = 60° F (extrapolated from full-scale motor firing data).

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Table IV

BALLISTIC PROPERTIES OF PNEUMATICALLY MIXED 15KS 1000 JATO PROPELLANT

Pressure (psi)	Burning Rate (in/sec.) PM #1*	PM #2*	PM #3*	Production Material*	SPIA**
500	0.29	0.29	0.36	0.25	0.24
800	0.34	0.32	0.38	0.27	0.29
1000	0.36	0.33	0.39	0.29	0.32

*Determined from slab firings.
**Determined from full-scale motor firings.

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The modifications to the pneumatic mix installation, in order to manufacture HB series composite propellants, have been completed. These include:

a. An air preheater and control unit so that process air can be maintained at elevated temperatures.

b. A liquid feed and control unit for metering and continuously blending the prepolymer and cross-linker.

c. A hot water circulating system for maintaining the liquid feed at elevated temperatures.

d. Thermocouples for remote temperature indication and recording have been installed and checked out.

e. The solid feed section, including an additional solid feeder for aluminum, has been repiped with the ammonium perchlorate feeder mounted on a loss-in-weight mechanism.

f. A weight sensor with a remote indicator and recorder for the propellant product has been installed.

An HB series propellant appears to be the best candidate for loading very large boosters. The propellant contains ammonium perchlorate and aluminum dispersed in a polybutadiene-acrylic acid-acrylonitrile terpolymer cured with a diepoxide.

Preliminary measurements of the physical properties of a batch mixed nominal HB series composite propellant formulation are tabulated below:

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Tensile Strength at 60° F ——— 148 psi
Elongation at 60° F ——— 36%

The ballistic properties of the HB series composite formulation are provided in Table V.

Inasmuch as this data was to be used for comparison purposes with pneumatically mixed material, the physical and ballistic properties were not optimized.

Data compiled on the rheological properties of the HB series composite propellant provided complete profiles of viscosity, time, temperature and rate of shear relationships.

The viscosity versus time relationship for the HB series propellant binder indicated that the binder viscosity increased from 3×10^3 to 9×10^3 centipoise when held for six hours at 140° F.

The viscosity versus time relationship for HB series dummy propellant showed an increased in propellant viscosity from 2×10^6 to 5×10^6 centipoise after six hours, at 140° F. The viscosity of the mixture at room temperature was so great as to render it immeasurable.

The viscosity versus rate of shear measurements at various temperatures indicated the need for processing the HB series propellant at elevated temperatures. An optimum temperature range for processing this formulation was established as 135-145° F. Above this temperature range the propellant binder no longer exhibits a decreasing viscosity with temperature because of the increased rate of polymerization.

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Table V

BALLISTIC PROPERTIES OF BATCH MIXED HB SERIES COMPOSITE PROPELLANT

Grain and Section	E615-A
$\overline{P}_b$ (psia)	963
$\overline{P}_a$ (psia)	922
B_r (in/sec)	.441
C_D (sec^{-1})	.006182
T_b (sec)	3.059
W_p (lbs)	7.735
PTIa (psia-sec)	3037
$\overline{F}_b$ (lbsf)	555
Isp Del. (sec)	226.1
Isp (1000-15°) (sec)	243.1
Isp (1000-0°) (sec)	247.3
Isp Alt. (sec)	285.3
C_f	1.39700

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CONCLUSIONS

Composite propellant was continuously mixed, cast and deaerated by means of the Pneumatic Mix Process. The cured product was homogeneous, dense and possessed ballistic and mechanical properties comparable to conventionally processed material.

FUTURE PLANS

No work on this program will be accomplished until funds are allocated for the continuation of the project.